An Ocean-atmosphere Simulation for Studying Air-sea Interactions

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Overall motivation of the research program

- Couple GEOS atmospheric model and MITgcm ocean model.
- Perform ocean analysis using the MITgcm 4D-var data assimilation capability.
- Develop a prototype ocean-ice-atmosphere weakly coupled data assimilation system by exploiting and leveraging GEOS and MITgcm data assimilation capabilities.

Applications

- Recent sea ice and ice sheet changes.
- Sub-seasonal to decadal climate predictions.
- Mesoscale air-sea interactions.
- Observation System Simulation Experiments (OSSEs).

Current state of project

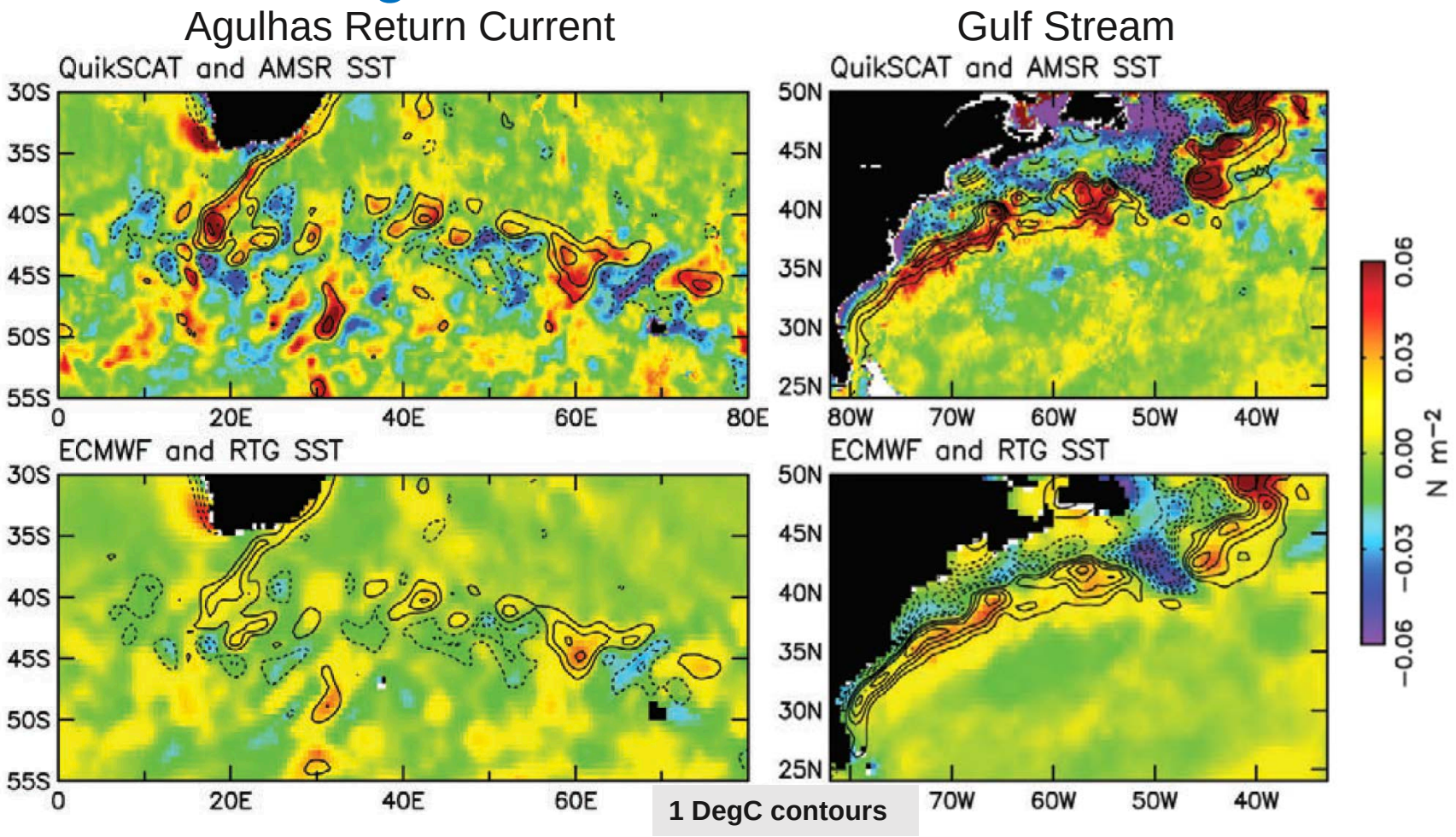
- GEOS-MIT model is now running with overall realistic results.
- Issues:
  - Too much net heat flux to the ocean (cloud forcing).
  - “The double ITCZ problem”
  - Too much accumulation of sea-ice in some regions (e.g. the Beaufort Sea).
- Tuning is about to commence using Green’s function method (Menemenlis *et al*., 2005).

Air sea interactions in the high resolution GEOS-MIT

Current objectives of this study

- Develop a high resolution coupled ocean-atmosphere run for studying air sea interactions and simulating an observation system.
- Investigate the ability of the coupled model to capture the strong observed positive correlations between SST and wind stress/speed.
- Compare near-surface diagnostics of the fully coupled ocean-atmosphere set-up to equivalent atmosphere-only simulations.

Background: observed SST/wind stress anomaly correlations



Two-month averages (January–February 2008) of **spatially high-pass-filtered sea surface temperature (SST)** overlaid as contours on **spatially high-pass-filtered wind stress.**

"Satellite observations have revealed a remarkably strong positive correlation between sea surface temperature (SST) and surface winds on oceanic mesoscales of 10–1000 km."

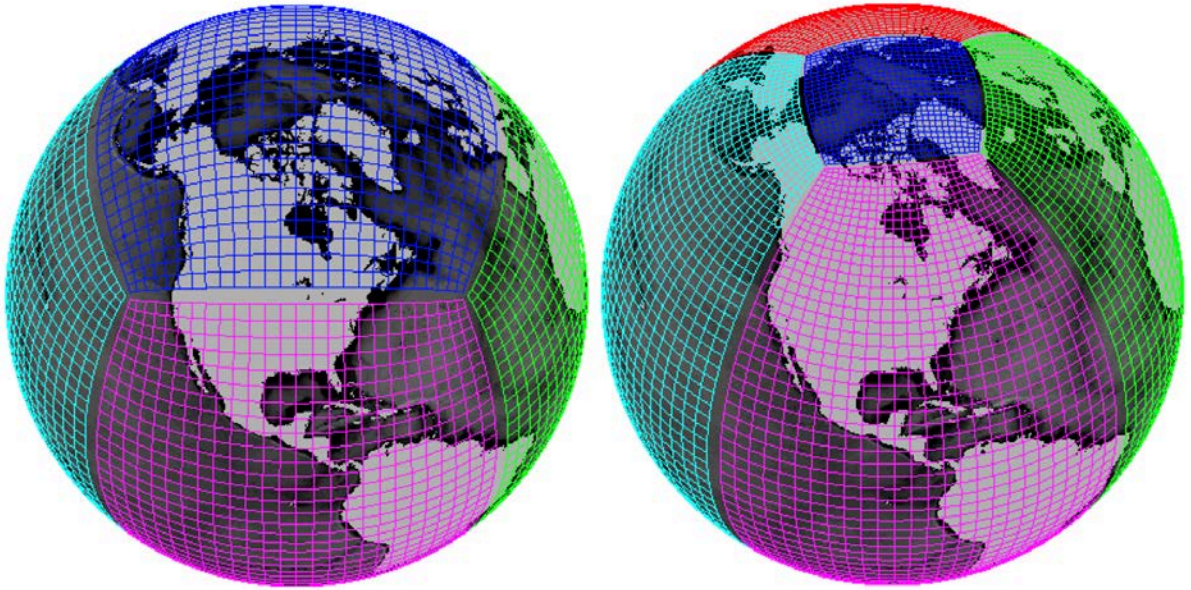
Chelton *et al., Oceanography (2010)*

… correlation between SST and surface wind stress, is realistically captured only when the ocean component is eddy resolving."

Bryan *et al., J. Clim. (2010)*

Methods - models

- Atmosphere – GEOS:
  - Horizontal grid type – Cubed sphere, 1/8° X1/8°
  - Vertical grid type – hybrid sigma-pressure, 72 levels
- Ocean – MITgcm
  - Horizontal grid type – Lat-Lon-Cap, 1/12° X1/12°
  - Vertical grid type – z^* rescaled height vertical coordinate, 90 levels

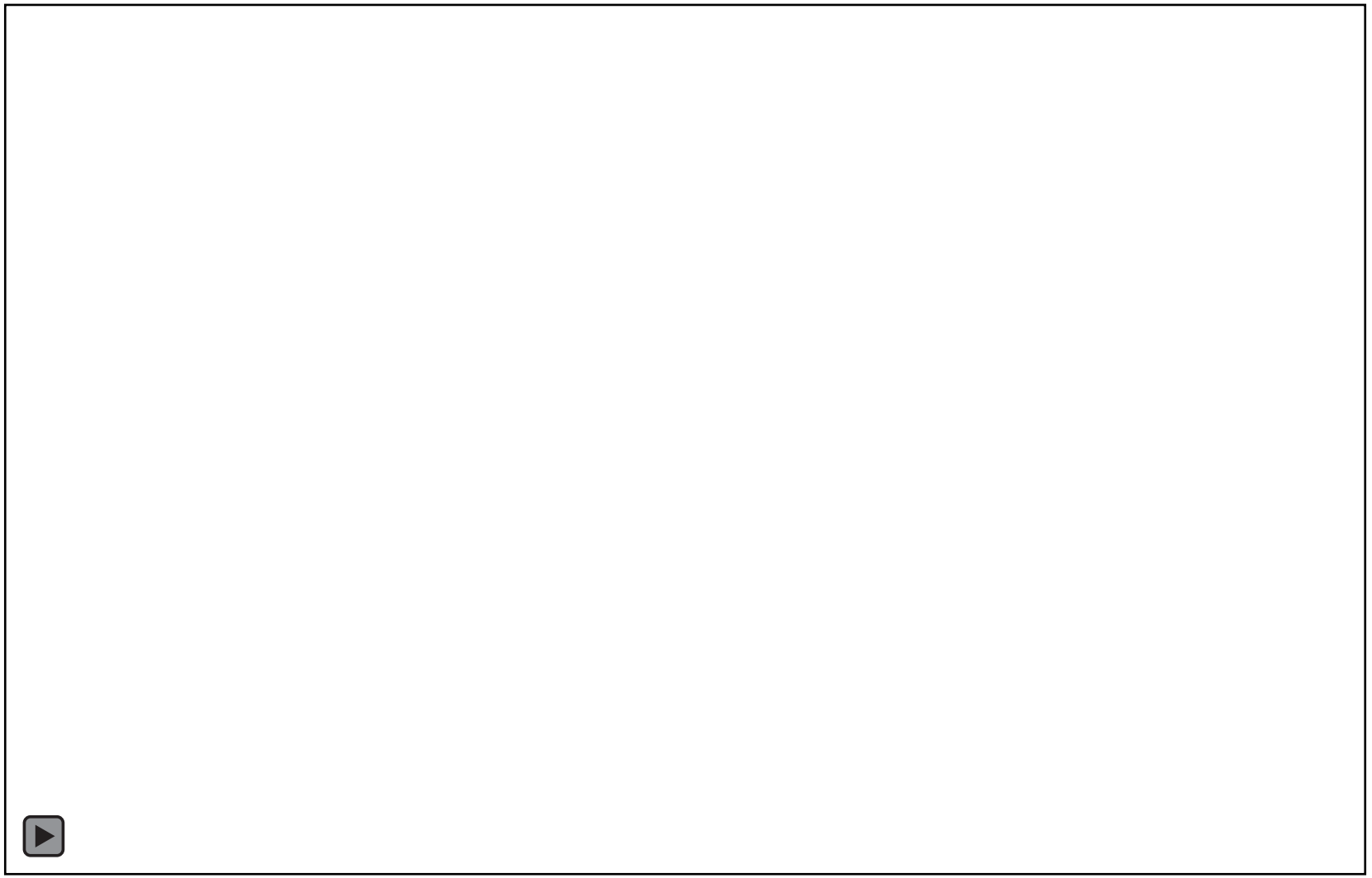


Cubed sphere grid (left) and Lat-Lon-Cap (right)

Methods - experimental setup

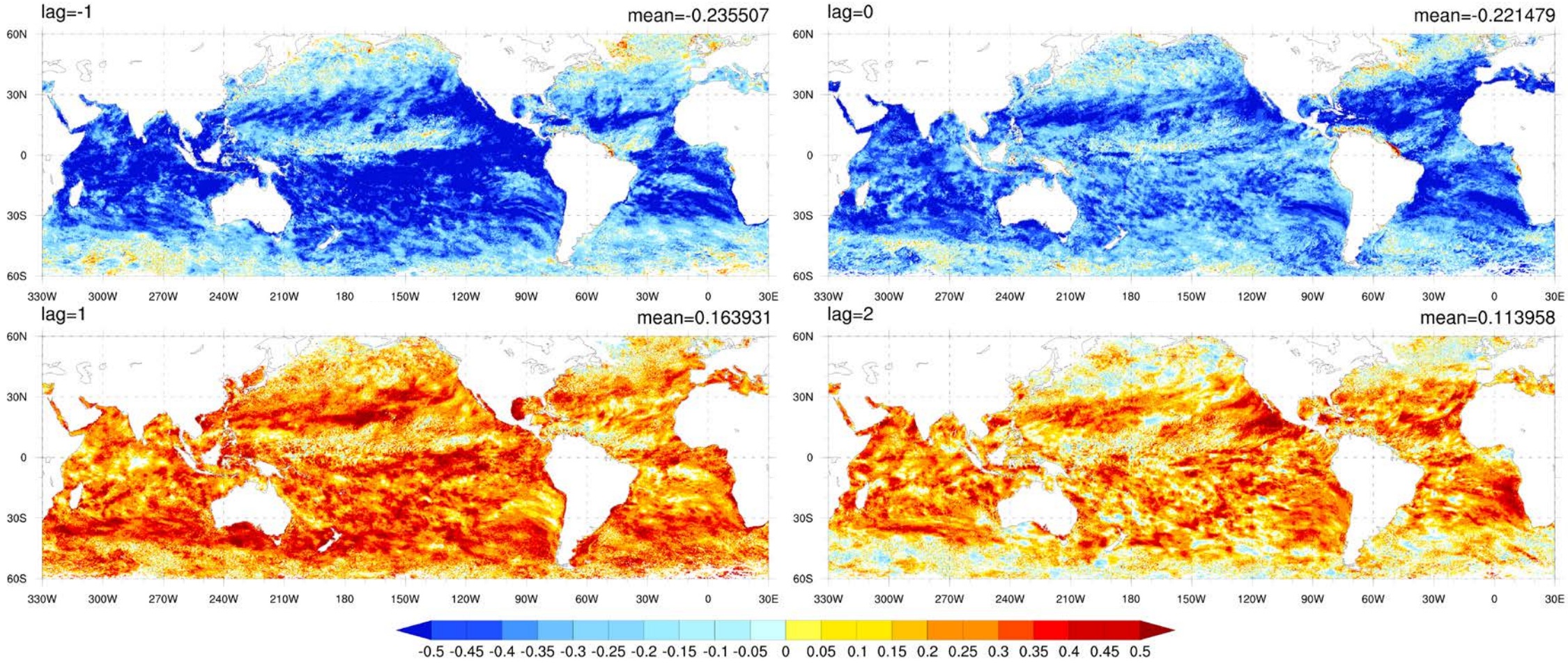
1) Atmosphere Only – GEOS (AGCM)
   - Feb, 9 – Apr 9, 2012
   - Forcing: SST and ice fraction from an equivalent ocean-only experiment
   - Initial conditions: MERRA-2
2) Coupled – GEOS-MITgcm (AOGCM)
   - Feb, 9 – Apr 9, 2012
   - Ocean initial conditions: from an equivalent ocean-only experiment
   - Atmospheric initial conditions: MERRA-2 (same as the run 1)

Ocean surface current



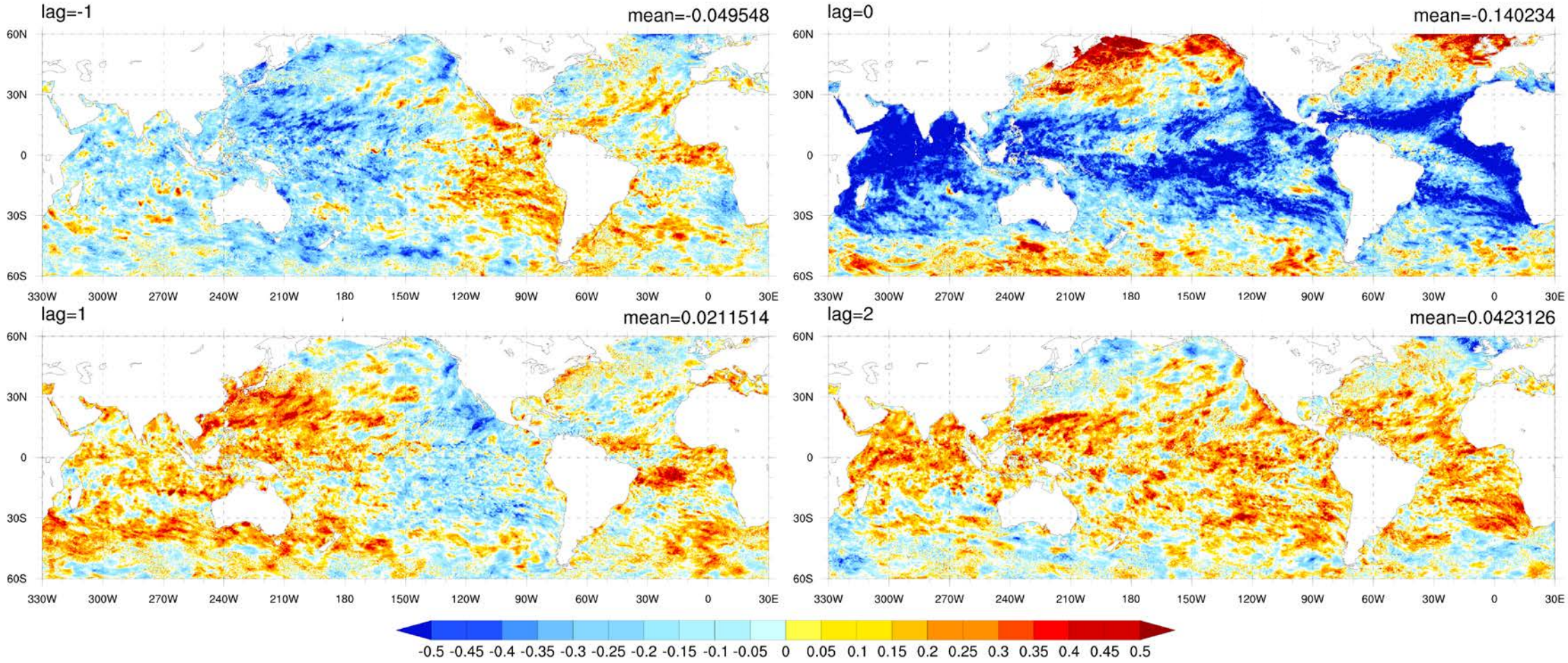
Lagged correlation between daily SST $\left(\frac{\Delta SST}{\Delta t}\right)$ and wind speed $\left(\frac{\Delta WS}{\Delta t}\right)$

GEOS-MITgcm

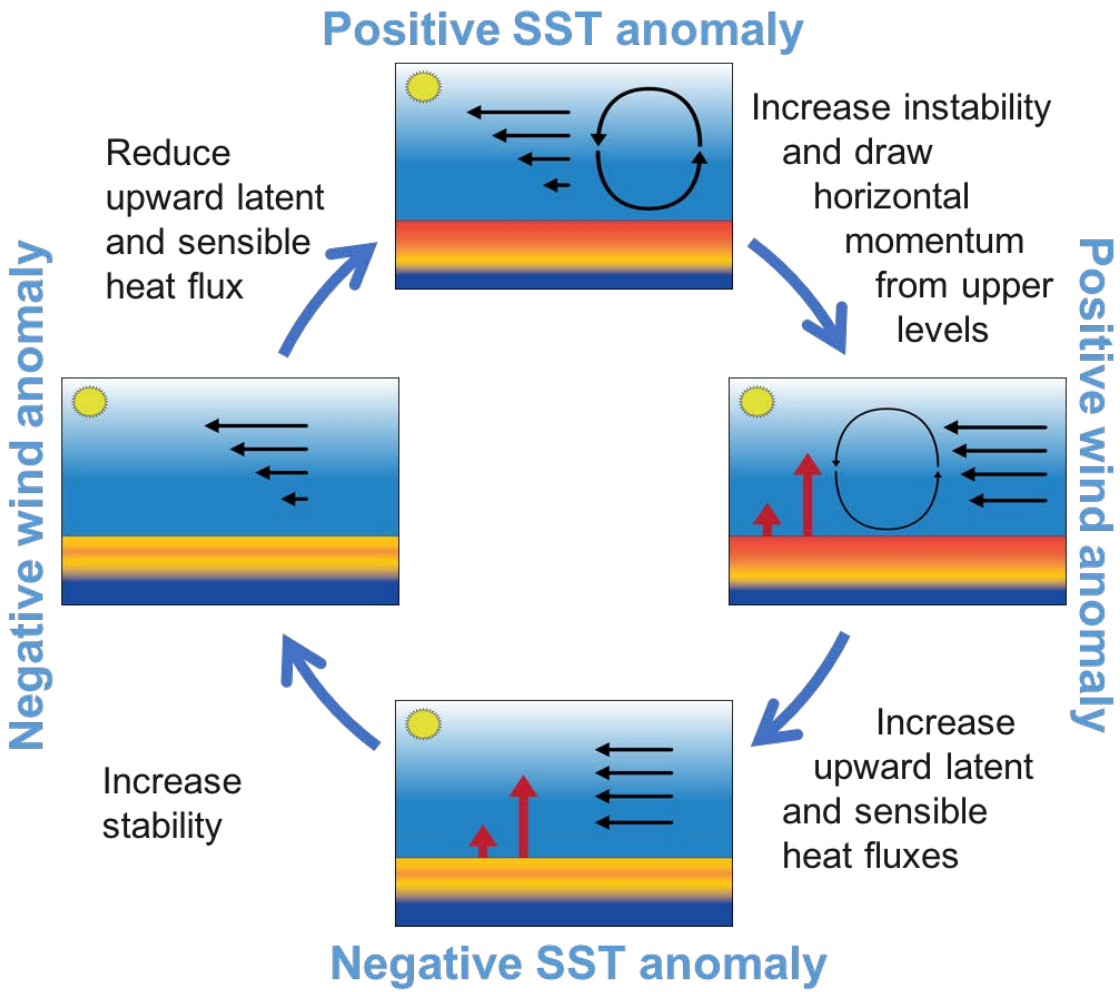


Correlation between daily SST $\left(\frac{\Delta SST}{\Delta t}\right)$ and wind speed $\left(\frac{\Delta WS}{\Delta t}\right)$

GEOS



Possible mechanism



Conclusions

- First analysis of the ~10km coupled GEOS-MITgcm model reproduces realistic synoptic and mesoscale patterns.
- The coupled model shows positive correlations between SST and wind speed/stress, and the relation is slightly closer to observational estimates compared to previous simulations.
- The fact that the atmosphere-only experiment can reproduce the positive correlation suggests that the atmosphere responds to the ocean.
- Daily time series suggest a three-four-day cycle induced by air-sea feedbacks.

Next steps/future work

- Model tuning using green's function method.
- Increasing horizontal resolution (~1km).
- Recent sea ice and ice sheet changes.
- Initialized sub-seasonal to decadal prediction system.
- Observation System Simulation Experiments (OSSE).

Computational Issues – Doubling the Resolution

1/16°X1/16° Atmosphere, 1/24°X1/24° ocean:

- Initialize/finalize - ~2 hours to initialize, ~1 hour finalize
- Node memory – using only 20 out of CPUs per 128GB node
- Pre/post processing (1 3D field ~21GB, ~0.5TB for restart file)
- Time stepping: ~1 time step per 15 sec
- SYNCIO/IOSERVER: parallel I/O